CLOSED NOZZLE TESTS
OF
FORTY GALLON CHEMICAL EXTINGUISHER

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ARMOUR INSTITUTE OF TECHNOLOGY

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Closed nozzle tests of a
 forty gallon chemical

Closed Nozzle Tests of a Forty Gallon Chemical Extinguisher

A THESIS

PRESENTED BY

A. Corman, R. D. Cowles, W. R. Owen
and W. P. Tronvig

TO THE

PRESIDENT AND FACULTY

OF

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IN

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PART I.

OBJECT

The pressure generated in an acid-soda chemical extinguisher of any size is due to the carbon dioxide gas (CO_2) evolved by the reaction between sulphuric acid (H_2SO_4) and sodium bicarbonate ($NaHCO_3$). The chemical reaction involved is as follows:

$$2\,NaHCO_3 + H_2SO_4 \rightarrow 2CO_2 + Na_2SO_4 + 2H_2O$$

Definite charges of acid, soda, and water are specified by the manufacturer as "normal" charges for extinguishers of each size. For the 40-gallon extinguisher used in these tests, the "normal" charges are 7 pounds of 66° Be. sulphuric acid, 20 pounds of commercial bicarbonate of soda, and 33 gallons of water. For these given charges of acid and soda, a definite amount of carbon dioxide gas will be generated, regardless of the volume of gas space or temperature of the solution.

According to Boyle's law the pressures due to a given weight of gas are inversely

proportional to the respective volumes of the gas at constant temperature. In other words, in the case of the 40-gallon extinguisher, the pressures developed by the reaction between normal charges of acid and soda at constant temperatures should vary inversely with the gas space above the solution, and should approach infinity as the gas space approaches zero. This condition is, however, modified due to the fact that as the pressure increases, increasing amounts of gas will go into solution.

Furthermore, Charles' law states that the pressure developed by a given weight of gas is directly proportional to the temperature, at constant volume. Thus, at a constant volume, the difference in pressure developed by the gas at 40 F. and 120 F. may be found from the following equation:-

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Substituting the above temperatures in absolute degrees Farenheit, in the equation, we find that the pressure developed at 120° F. is 1.16 times the pressure developed at 40°F. This figure is not exactly correct due to the fact that a certain amount of heat will be evolved from the reaction raising the temperatures of the gas above 40° F. and 120° F; but the change in the ratio would be negligible. This relation shows that the variation in pressure, due to the temperature alone, is not great. Another factor, however, enters which makes this variation much greater; i.e., the greater solubility of CO_2 gas at the lower temperatures. Approximately 3.14 grams of CO_2 gas will dissolve in 1000 grams of water at 40° F. while only .74 grams will dissolve at 120° F. This means that the amount of available gas to generate pressure at the lower temperatures will be less than at the

higher temperatures using the same charges.

The amount of gas generated in the reaction will vary with the weights of acid and soda used, thus varying the pressures developed.

Hence the pressure developed in a Chemical Extinguisher is a function of four variables: viz., air or gas space, temperature, and weights of acid and soda.

The object of this investigation is to determine the effect of variations in these four factors upon the maximum pressures developed in the extinguisher with closed nozzle.

PART II.

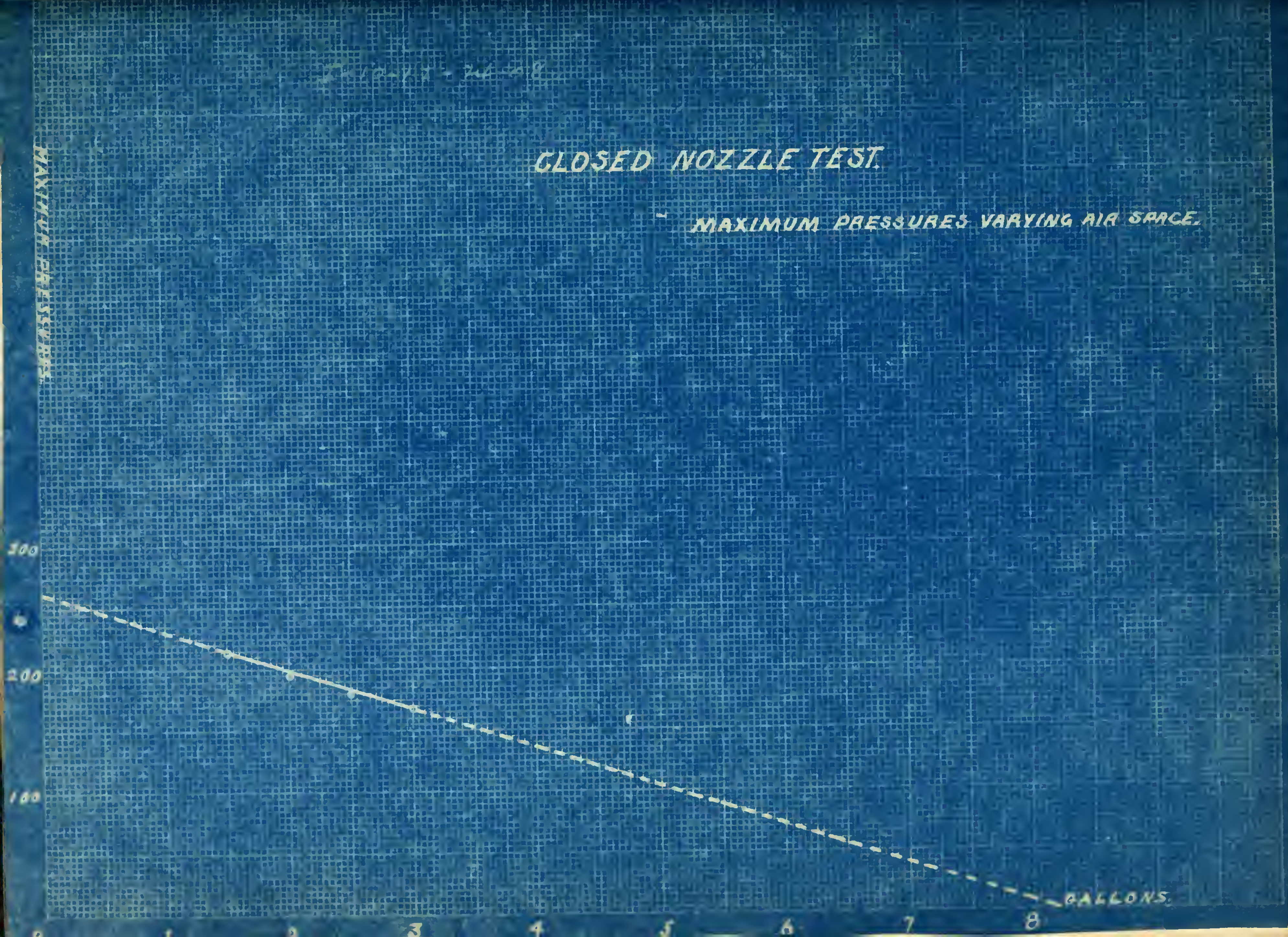
INTRODUCTION

In testing a given extinguisher, Underwriters' Laboratories, usually subject it to certain standard operating tests, in which the temperature, and occasionally the weight of acid, is varied, other factors being maintained constant at normal values. The purpose of these tests is to observe the character of the stream, the variation in pressure during the test, and whether the stream is acid or alkaline. In short, the object is to determine the effectiveness of operation of the extinguisher, using normal charges at various temperatures.

Comparatively little investigation has been made to determine the effect upon the operating characteristics of the chemical fire extinguisher of varying the other factors. Previous work along this line includes a set of observations made in 1908, upon the "Effect of excess water charges on the maxi-

mum possible pressure in a 40-gallon extinguisher", and described as follows:

> "These tests were made with nozzle closed. 7# of acid and 20# of soda were used for each test. The temperature is not stated, but was in the neighborhood of 45° F.(Solution).
>
> Ineach case the engine was charged, hose filled with water and nozzle closed. The amount of net gas space above the water was carefully determined in each case. The engine was then inverted and allowed to register its maximum pressure. These maximum pressures were then plotted against initial gas space expressed in gallons.
>
> Four tests were made. The solid portion of the curve drawn through these points is, of course, in accordance with the test data, but the det-


CLOSED NOZZLE TEST.
MAXIMUM PRESSURES VARYING AIR SPACE.
MAXIMUM PRESSURES
300
200
100
GALLONS.
0
1
2
3
4
5
6
7
8

> ted extensions are probably in error. The left end of the curve would probably rise much higher if it were defined by actual data; the curve, no matter how far extended to the right would probably not drop below 125 lbs. for the chemical charges of the magnitude used in the test."

These tests were intended to yield data only indicative of the general tendency of the air-space pressure curve, for the temperature was not definitely known, the addition of the hose, though filled with water, possibly introduced an error due to its expansibility, and the four observations recorded were not sufficient to define the curve over an extended range.

The desire for more definite results as to the effect of varying not only the amount of water, but also the weights of acid and

soda, and the temperature, furnish the justification for this series of tests.

As a result of the present investigation, the following groups of curves are hereinafter included:

1. The relation between net gas space and maximum pressures at various temperatures. These curves should, theoretically, be of the general nature indicated in Fig. A, for as the ratio of air-space to solution approaches zero, i.e., the actual air space approaches zero, the maximum pressure generated should approach infinity; and as the ratio of air space to solution approaches infinity, i.e., as the amount of solution approaches zero, the pressure generated should, at each of the various temperatures, approach a constant value.

2. The relation between temperature and pressure at normal charges and with varying charges of acid, soda and water. The

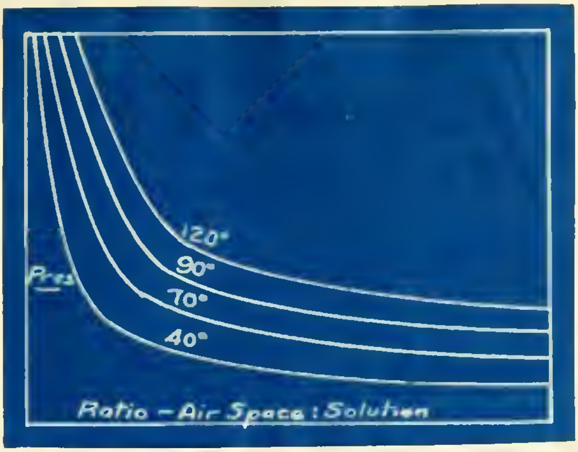


Fig. 1.

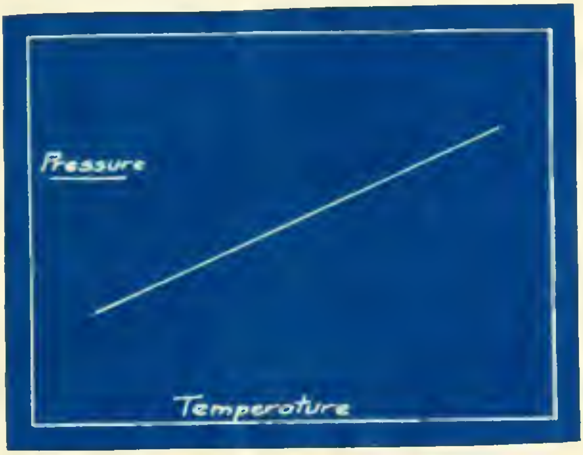


Fig. 2.

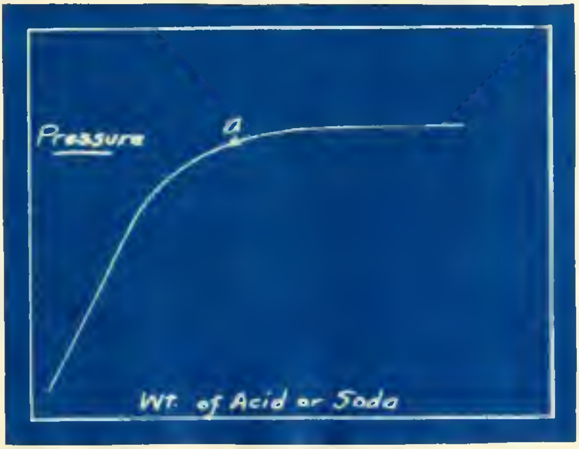


Fig. 3.

theoretical nature of this curve is as shown in figure "B", in which, the pressure varies directly with the temperature due principally to the fact that more CO_2 gas dissolves at the lower temperatures leaving less gas available for generating pressure; and to a lesser extent in accordance with Charles Law.

3. The relation between weights of acid, and pressure, other factors remainung constant. This curve should, theoretically, be as indicated in figure "C", for the amount of gas generated, and hence the maximum pressures, will increase as the weight of acid increases until the point "a" is reached corresponding to the weight of acid which will completely act with a given weight of soda. Beyond "a", where an excess of acid is added, the pressure should remain constant, since the amount of gas generated remains constant.

4. The relation between weights of soda,

and pressure, other factors remaining constant. The general form of these curves will be that indicated in figure "C", for the reasons given above.

PART III.

ACTUAL TEST.

CHAPTER 1.

TEST APPARATUS.

The essential part of the test apparatus was the extinguisher itself. It is shown in the accompanying photograph, (Fig. 1.) and comprised the main tank (T) of 40 gallons capacity, the cage (C) in which the acid bottle (A) rested, and the cover (B). The tank itself was of seamless cold drawn steel. A head of the same construction was riveted to the main shell, as shown in figure 2, and the whole seam was backed with a heavy body of solder, protecting the seam and rivets from any possible attack by presenting a smooth interior where no corrosive sediment could lodge. The overall dimentions were: length, 49 inches; diameter, 23 7/8 inches; height, 52 inches. The cage was of heavy cast brass, protected against corrosion and rested on projections in the neck of the tank. It was of such length that the level of 33 gallons of water,

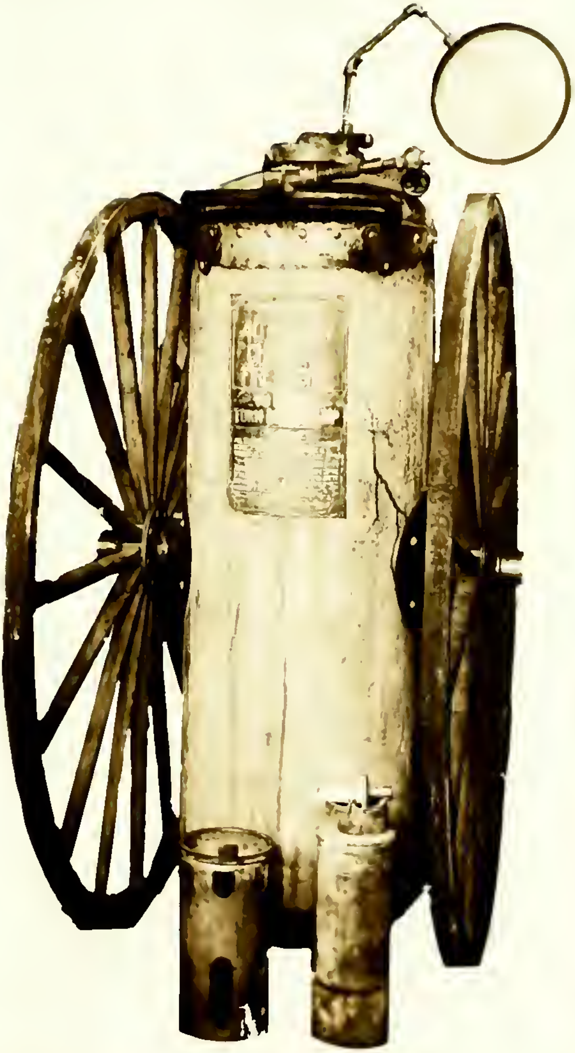


Fig. 1. Extinguisher upright,
showing gauge, acid bottle, etc.
and hose.

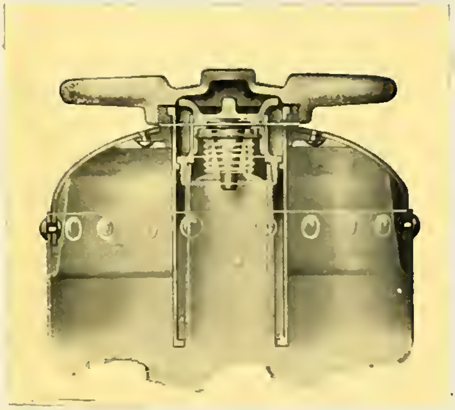


Fig. 2

Cross-section thru top of tank.

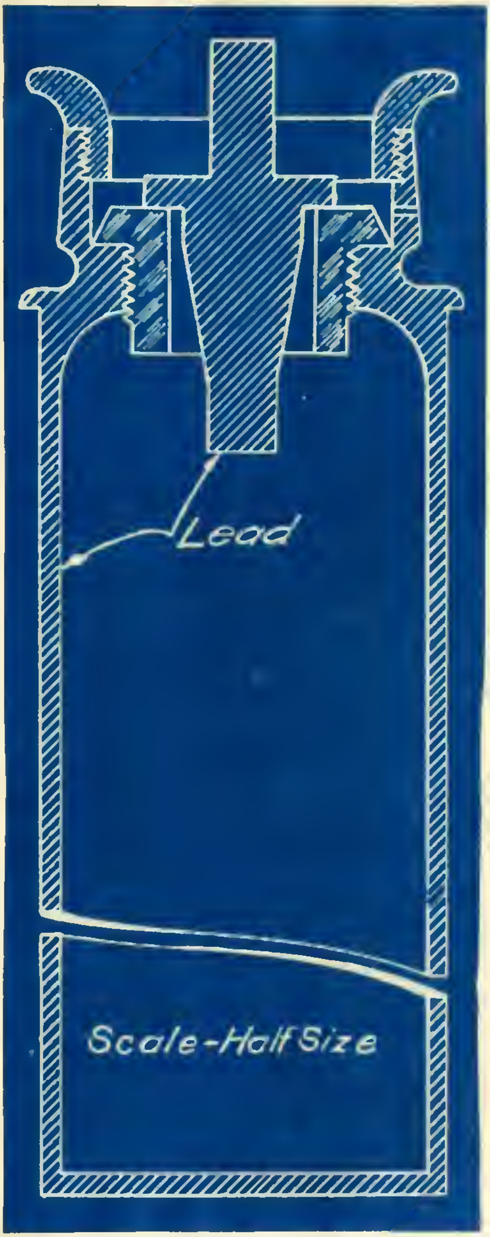


Fig. [illegible].-Cross-section of Acid Bottle and Stopple.

the normal charge, just reached its lower surface and thus served as an indicator for filling. Its main function was to support the acid bottle, the detailed construction of which is shown in figure 3, The bottle was of lead, with a glass neck affording a non-sticking seat for the lead stopple and was supported by the projecting elements B-B. A lead stopple fitted loosely in the neck of the acid bottle.

Auxiliary apparatus included a 300#, and a 500# gauge, thermometer, six foot rule, scales, soda pail and funnel, stirring rod six feet long (wood) and a one gallon measure.

CHAPTER 2.

TEST METHOD.

As it was desired in the course of the investigation to use various volumes of water, the first step was to devise a quick method of getting any desired volume of water into the tank. It would not be feasible to use a 1-gallon measure each time the tank was filled, so a preliminary set of data was taken showing the height of the water level below the top of the tank for one gallon intervals of volume. The amount of water put into the tank was measured with a 1-gallon measure of especially accurate construction; it was conical in shape, the top of the measure being about 1 1/2 inches in diameter. As each gallon was added, the height of the water level below the top of the tank was measured with an ordinary six foot rule. Heights were measured at one gallon intervals from fifteen gallons to forty gallons, three series of readings being taken, and the

average values used in the succeeding tests.

The tests were made with "closed nozzle" in order to give results which might be considered more nearly standard, for the pressure developed would vary somewhat with the kind of hose and nozzle used. It was felt that the results obtained could readily be translated into terms of "open nozzle" pressures by running a few tests to show the relation between these maximum closed nozzle pressures and the maximum obtained under open nozzle conditions with hose attached. The hose was detached for these tests for it would be necessary, in order to eliminate errors due to capacity of the hose, to fill it with water before each run; and it was thought easier to detach the hose once and for all, and substitute simply a shut-off valve thru which the pressure might be blown off.

In operating the machine, the desired charge of water was first run in and brought to the proper temperature by running either hot or cold water as required, from the house system over the tank. The soda charge was then poured in and thoroughly stirred until there was no doubt of its complete solution. The height of the solution level below the top of the tank was measured. The acid charge was then weighed out and the cage, acid bottle and stopple put in place, the cover screwed on tightly, gauge screwed on and valve "C" closed. The machine was then inverted, as shown in figure 4. This inverted the acid bottle allowing the acid to run out and react with the soda solution. The flow of acid was governed by the space between the top of stopple and the bottom of cover, which was about 1/2 inch. The actual area between the stopple and the neck of the acid

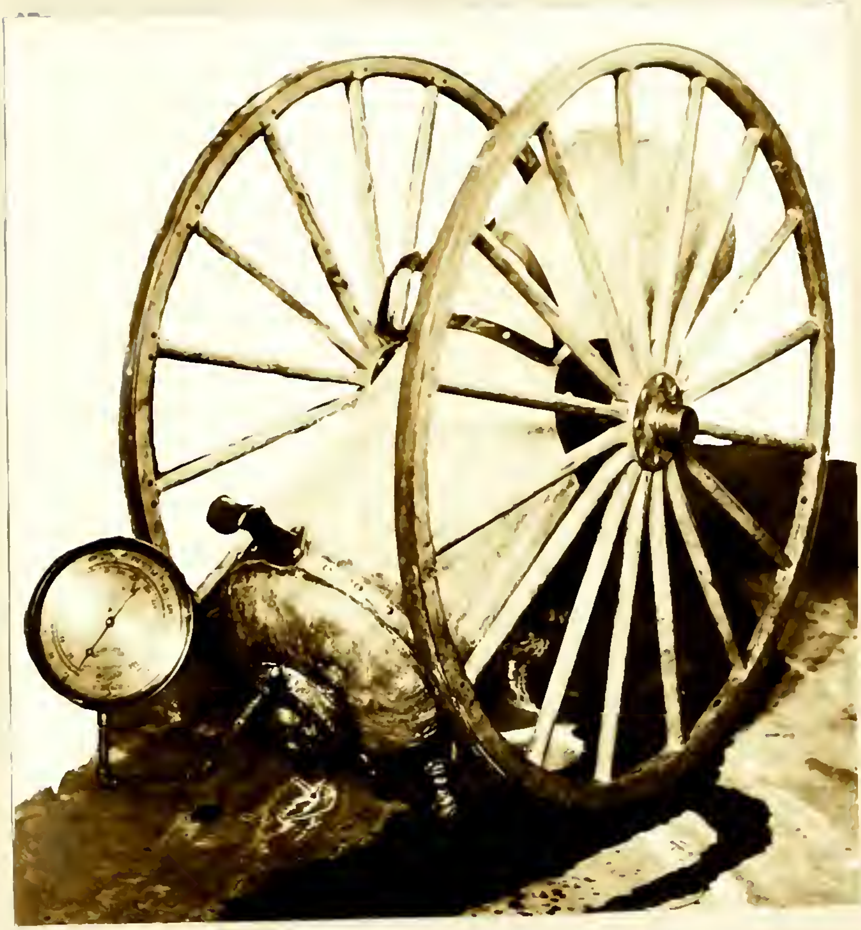


Fig. 4.-Extinguisher in Operating Position.

bottle in this inverted position was .54 square inches. When the maximum pressure had been reached, the shut-off valve "C" was opened and the contents of the tank discharged thru it. When all the pressure had been released the cover was taken off and the tank and acid bottle thoroughly cleaned before proceeding with the next run.

It was found that after the maximum pressure had been attained, the machine was uprighted when the pressure rose above the previous maximum, indicating that not all of the acid had reacted while the machine was inverted. It is felt that these "maxima after shaking" indicate the true maximum pressures, since these are the pressures attained when all the acid and soda have reacted.

Four groups of runs were made as follows:

(1) Varying the air-space, with constant (normal) weights of acid and soda; runs made at 40°, 70°, 90°, and 120° F.

(2) Varying the temperature, with normal charges.

(3) Varying the weight of acid, with constant (normal) solution and weight of soda; runs made at 40°, 70°, 90°, and 120° F.

(4) Varying the weight of soda, with constant (normal) solution and weight of acid; runs made at 40°, 70°, 90°, and 120° F.

In each run pressure readings were taken at regular intervals (generally 5 seconds) so that curves might be drawn if desired, showing the rate of increase in pressure. A total of about sixty runs were made, in the most convenient order and later arranged in the four groups indicated above.

PART III. CHAPTER I.

TEST-DATA-AND-CURVES.

TEST DATA.

CAPACITY TEST.

Gals.	Distance from top of Tank.(In.)			
	Run # 1.	Run # 2.	Run # 3.	Average.
15	31 1/4			
15	31 1/4	31 1/4	31 1/4	31.25
16	30 1/8	30 1/8	30 1/8	30.12
17	29 1/16	29	29	29.02
18	27 3/4	27 13/16	27 3/4	27.77
19	26 11/16	26 11/16	26 9/16	26.65
20	25 1/2	25 1/2	25 1/2	25.50
21	24 3/8	24 3/8	24 3/8	24.38
22	23 1/4	23 1/8	23 3/16	23.19
23	22 1/16	22 1/8	21 15/16	22.04
24	20 7/8	20 15/16	20 15/16	20.92
25	19 13/16	19 7/8	19 3/4	19.81
26	18 5/8	18 5/8	18 9/16	18.60
27	17 7/16	17 1/2	17 3/8	18.44
28	16 5/16	16 5/16	16 5/16	16.31
29	15 3/16	15 1/16	15 1/8	15.12
30	14 1/16	13 7/8	13 7/8	13.94
31	12 7/8	12 3/4	12 7/8	12.83
32	11 3/4	11 5/8	11 3/4	11.71
33	10 9/16	10 7/16	10 9/16	10.52
34	9 7/16	9 5/16	9 3/8	9.38
35	8 1/4	8 1/8	8 1/4	8.21
36	7 1/16	7 1/8	7	7.06
37	5 3/4	5 13/16	5 11/16	5.75
38	4 7/16	4 1/2	4 3/8	4.44
39	3 1/16	3 1/8	3 1/16	3.08
40	15/16	-----	11/16	.54

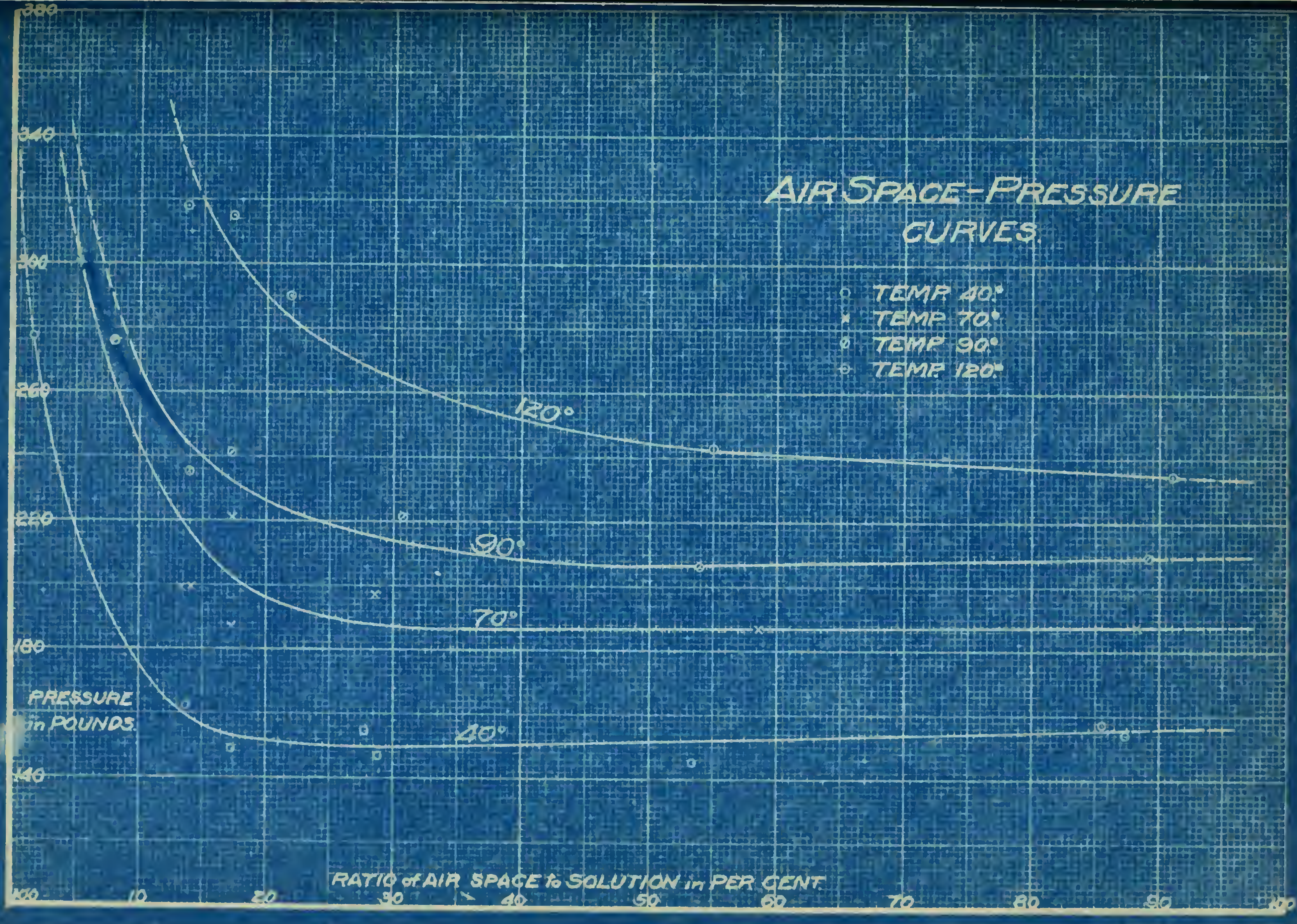
CAPACITY OF TANK----40 gals. & 1 pint.

TEST DATA.

AIR SPACE-PRESSURE DATA.

Acid 7 lbs.
Soda 20 lbs.

Run No.	Vol. of Water	Sol. level from top of tank	Vol. of Air-space	Vol. of Sol.	Ratio of Air-space / Solution	Max. Pres.	Max. after shaking.
	Gals.	Inches	Gals.	Gals.	%	#/□"	#/□"
			TEMPERATURE-40° F.				
1	20	24 5/16	18.47	21.06	85.50	157.5	---
5	33	9 3/4	5.85	33.68	17.38	147.0	---
9	25	18 7/8	13.75	25.78	53.45	145.5	---
16	30	13 3/16	8.85	30.68	28.80	146.6	149.0
52	30	13	8.63	30.9	27.94	154.5	153.0
17	34	8 1/2	4.78	34.75	13.76	162.3	173.0
62	38	3 1/4	.65	38.88	1.67	276.0	305.0
61	20	24 1/4	18.42	21.11	87.40	154.0	154.0
			TEMPERATURE-70° F.				
2	20	24 3/8	18.53	21.00	88.30	188.0	---
12	25	19 1/8	14.96	25.57	58.55	187.0	---
13	30	13 1/8	8.79	30.74	28.60	197.5	---
6	33	9 3/4	5.85	33.68	17.38	187.5	---
14	33	9 3/4	5.85	33.68	17.38	187.8	244.0
57	33	9 3/4	5.85	33.68	17.38	221.0	225.0
15	34	8 3/8	4.67	34.86	13.39	197.0	246.0
55	34	8 5/8	4.88n	34.65	14.08	197.0	270.0
58	37	5	1.96	37.57	5.22	300.0	304.0
			TEMPERATURE-90° F.				
3	20	24 1/2	18.64	20.89	89.20	210.0	---
10	25	19	13.86	25.67	53.96	216.0	---
19	30	13 3/16	8.85	30.68	28.82	221.0	226.0
8	33	9 3/4	5.85	38.68	17.38	241.0	---
20	34	8 9/16	4.83	34.70	13.91	235.0	303.0
60	36	6 1/4	2.91	36.62	7.94	276.0	359.0
			TEMPERATURE-120° F.				
4	20	24 5/8	18.83	20.70	91.00	235.0	---
11	25	19 3/16	14.02	25.51	55.00	242.7	---
18	30	13 1/16	8.74	30.79	21.91	290.0	293.0
7	33	9 3/4	5.85	33.68	17.38	315.0	---
23	34	8 1/2	4.78	34.75	13.77	318.0	395.0



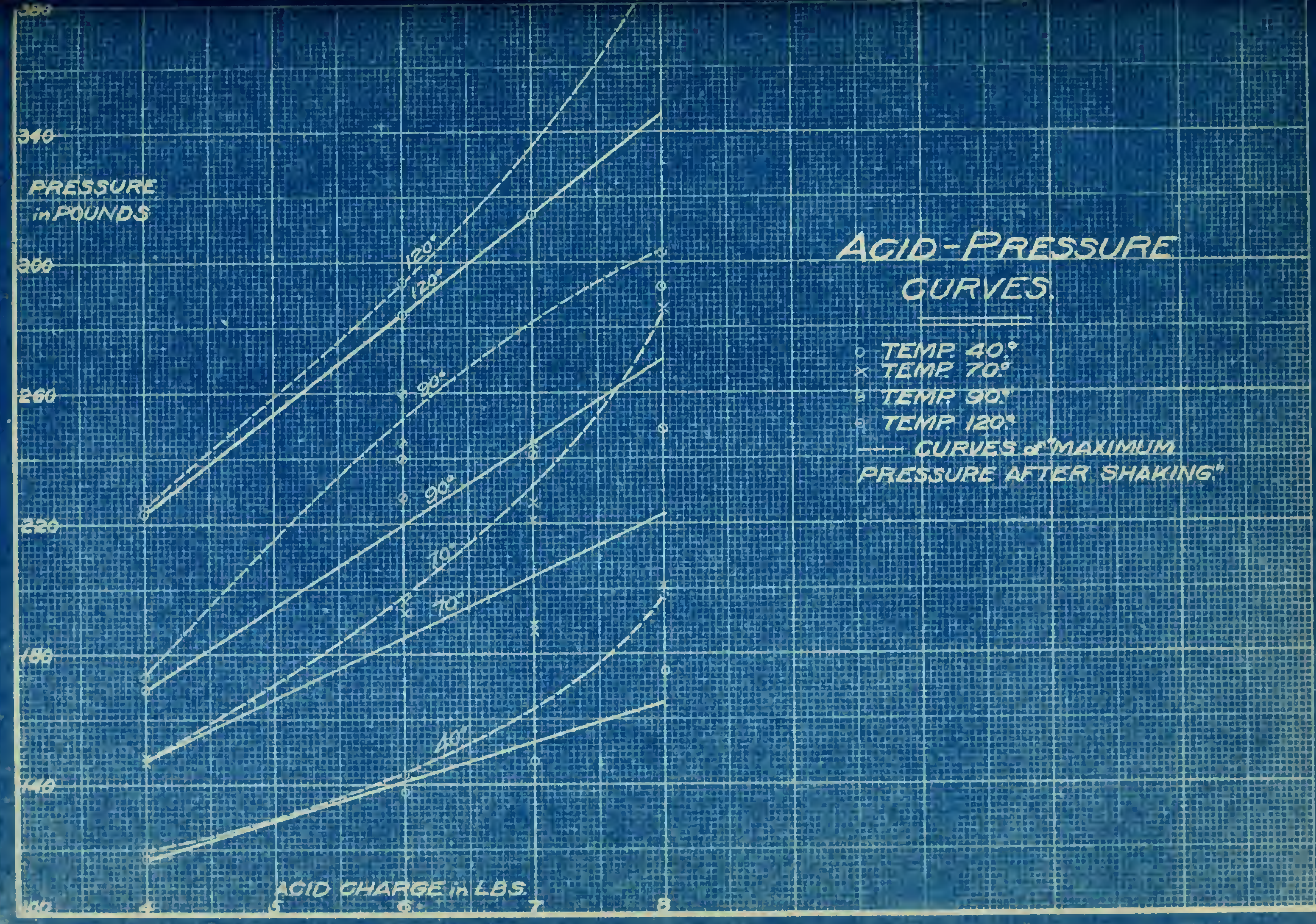
AIR SPACE-PRESSURE CURVES.

TEST DATA.

ACID-PRESSURE DATA.

Water 33 gals.
Soda 20 lbs.

Run No.	Wt. of Acid	Max. Press.	Max. after Shaking
	Lbs.	#/□"	#/□"
TEMPERATURE-40° F.			
21	4	117.5	119.0
25	6	138.8	143.0
5	7	147.0	---
28	8	174.5	198.0
TEMPERATURE-70° F.			
53	4	146.5	148.0
59	6	193.0	196.0
29	4	148.3	151.0
57	7	221.0	225.0
6	7	187.5	---
14	7	137.8	244.0
51	7	191.0	226.0
30	8	208.5	286.0
TEMPERATURE-90° F.			
24	4	169.2	173.0
26	6	240.0	245.0
32	6	228.0	260.0
8	7	241.0	---
31	8	249.0	303.0
TEMPERATURE-120° F.			
27	4	223.0	225.0
33	6	284.0	294.0
7	7	315.0	---
36	8	292.5	396.0
59	8	387.0	393.0

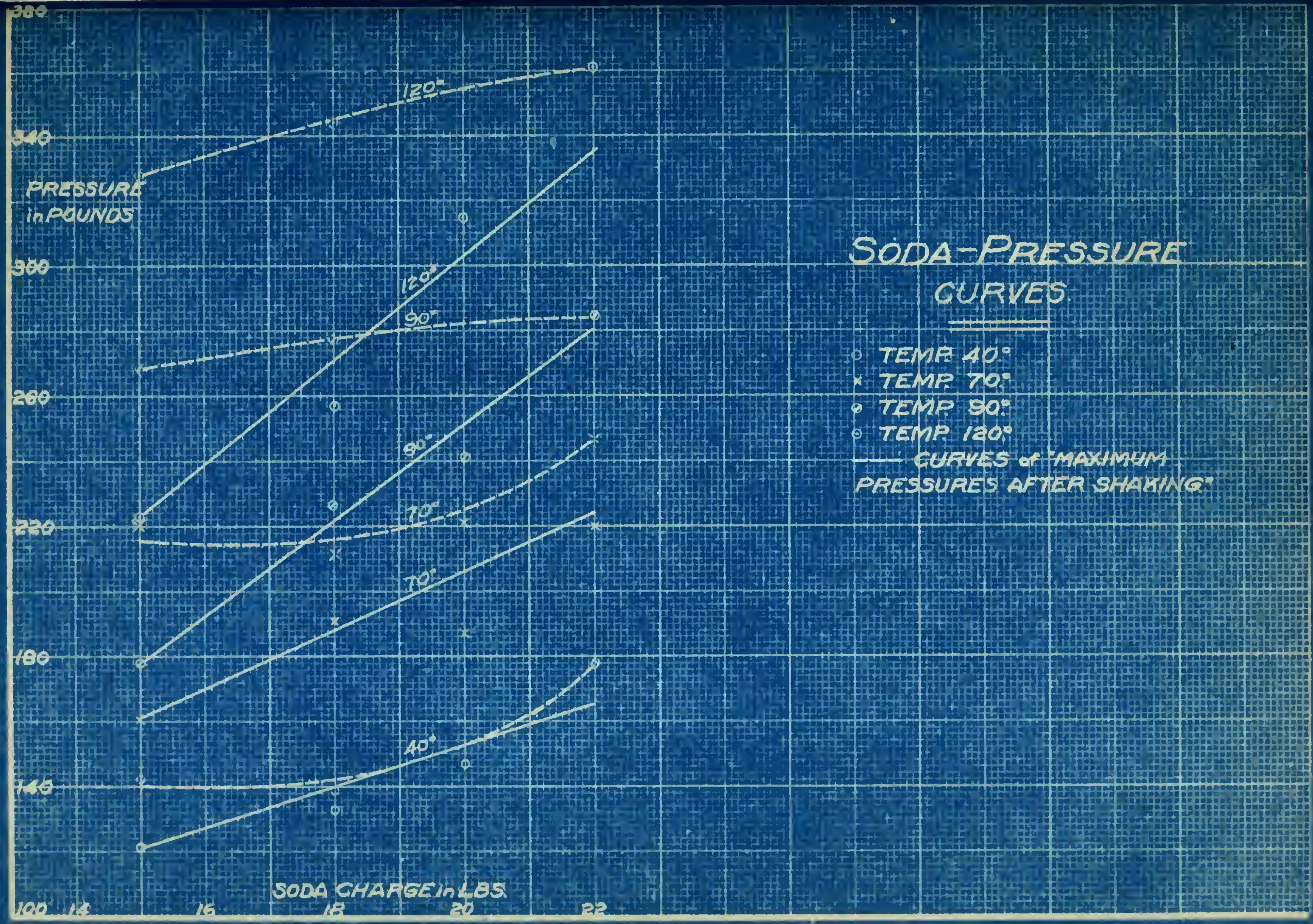

ACID-PRESSURE
CURVES.
○ TEMP. 40°
× TEMP. 70°
⊙ TEMP. 90°
⊙ TEMP. 120°
—— CURVES of "MAXIMUM PRESSURE AFTER SHAKING."
PRESSURE in POUNDS
ACID CHARGE in LBS.
380
340
300
260
220
180
140
100
4
5
6
7
8
120°
120°
90°
90°
70°
70°
40°

TEST DATA.

SODA PRESSURE DATA.

Water 33 gals.
Acid 7 lbs.

Run No.	Wt. of Soda	Max. Press.	Max. after Shaking
	lbs.	#/□"	#/□"
	TEMPERATURE-40° F.		
34	15.0	120.8	142.0
35	18.0	132.5	139.0
5	20.0	147.0	---
37	22.0	176.5	177.0
	TEMPERATURE-70° F.		
38	15.0	161.0	221.0
39	18.0	191.0	212.0
14	20.0	187.8	244.0
6	20.0	187.5	221.0
57	20.0	221.0	221.0
40	22.0	220.0	247.0
	TEMPERATURE-90° F.		
41	15.0	178.0	269.0
43	18.0	226.3	277.0
8	20.0	241.0	---
45	22.0	284.0	285.0
	TEMPERATURE-120° F.		
42	15.0	222.5	328.0
44	18.0	257.0	342.0
7	20.0	315.0	---
46	22.0	361.0	361.0


SODA-PRESSURE
CURVES
○ TEMP. 40°
× TEMP. 70°
⊙ TEMP. 90°
⊙ TEMP. 120°
—— CURVES of "MAXIMUM PRESSURES AFTER SHAKING"
PRESSURE in POUNDS
SODA CHARGE in LBS.
380
340
300
260
220
180
140
100
14
16
18
20
22
120°
120°
90°
90°
70°
70°
40°

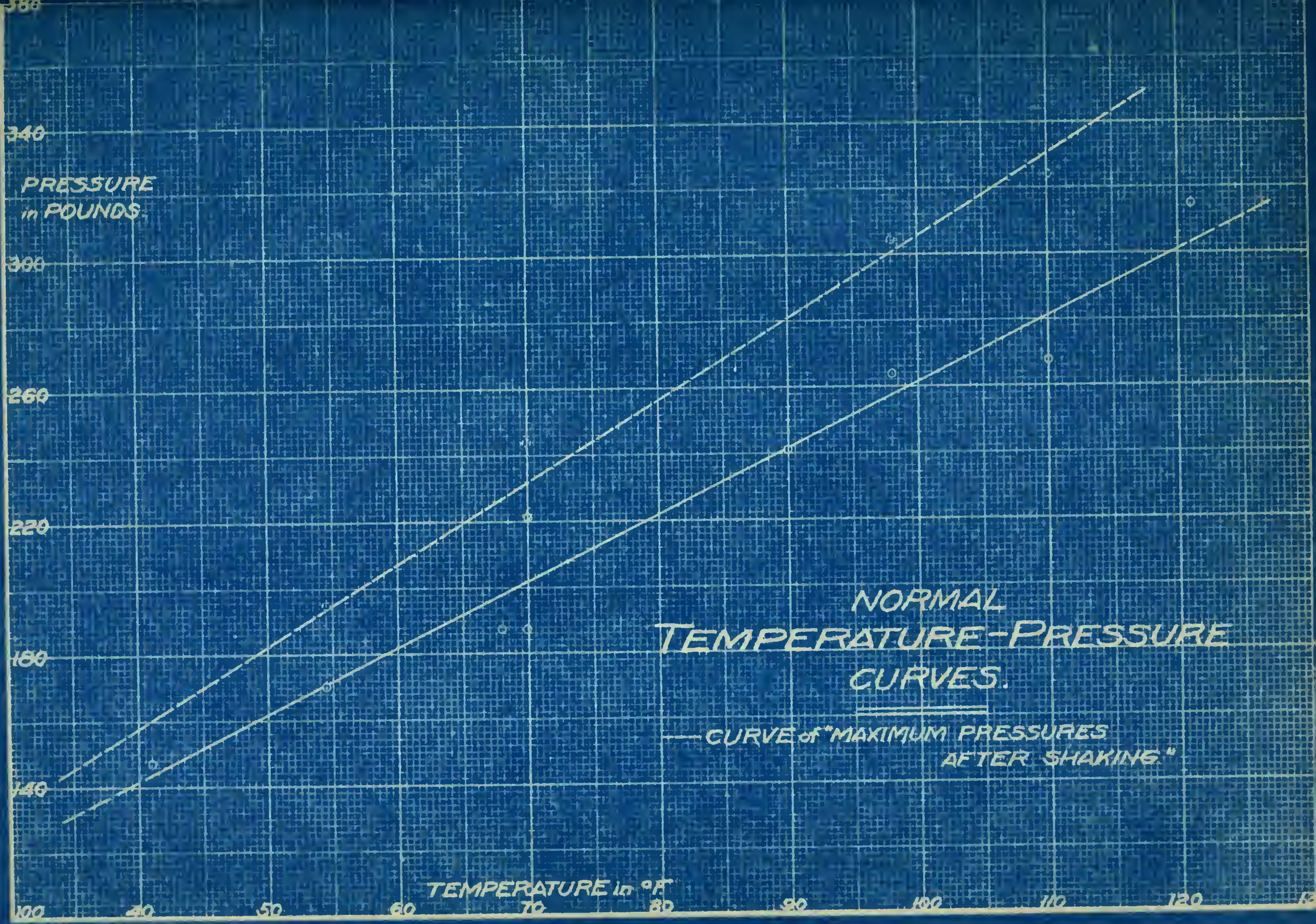
TEST DATA.

TEMPERATURE-PRESSURE DATA.

-NORMAL CHARGE-

Water	33 gals.
Acid	7 lbs.
Soda	20 lbs.

Run No.	Temp.	Max. Press.	Max. after Shaking
	°F.	#/□"	#/□"
5	41	147.0	---
47	54	170.0	195.0
6	68	187.5	---
14	70	187.8	244.0
57	70	221.0	221.0
8	90	241.0	---
48	98	264.0	304.0
56	110	268.0	324.0
7	121.	215.0	---


NORMAL
TEMPERATURE-PRESSURE
CURVES.
—CURVE of "MAXIMUM PRESSURES
AFTER SHAKING."
PRESSURE
in POUNDS.
380
340
300
260
220
180
140
100
TEMPERATURE in °F.
40
50
60
70
80
90
100
110
120

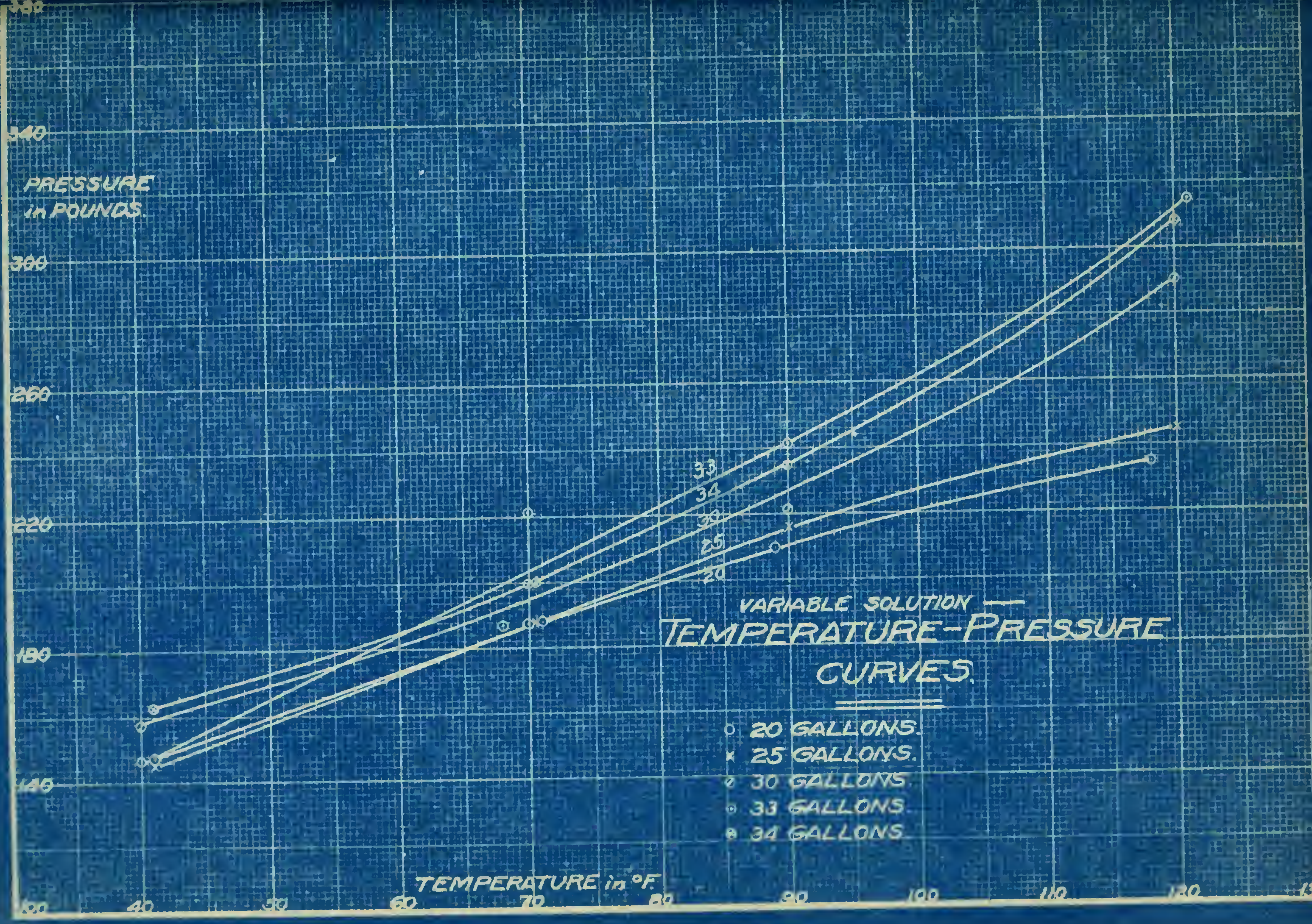
TEST DATA.

TEMPERATURE-PRESSURE DATA.

VARIABLE SOLUTION

Acid 7 lbs.
Soda 20 lbs.

Run No.	Temp.	Max. Press.	Max. after Shaking
	°F.	#/□"	#/□"
WATER CHARGE--20 gals.			
1	40	157.5	---
2	71	188.0	---
3	89	210.0	---
4	118	235.0	---
WATER CHARGE--25 gals.			
9	41	145.5	---
12	70	187.0	---
10	90	216.0	---
11	120	242.7	---
WATER CHARGE--30 gals.			
16	40	146.6	149.0
13	70	197.5	---
19	90	221.0	226.0
18	120	290.0	293.0
WATER CHARGE--33 gals.			
5	41	147.0	---
14	70	187.8	244.0
57	70	221.0	221.0
6	68	187.5	---
8	90	241.0	---
7	121	315.0	---
WATER CHARGE--34 gals.			
17	41	162.3	173.0
15	70	197.0	246.0
20	90	235.0	303.0
23	120	318.0	395.0


VARIABLE SOLUTION —
TEMPERATURE-PRESSURE
CURVES.
○ 20 GALLONS.
× 25 GALLONS.
⊘ 30 GALLONS
⊙ 33 GALLONS
⊗ 34 GALLONS
PRESSURE
in POUNDS.
340
300
260
220
180
140
TEMPERATURE in °F.
40
50
60
70
80
90
100
110
120
33
34
30
25
20

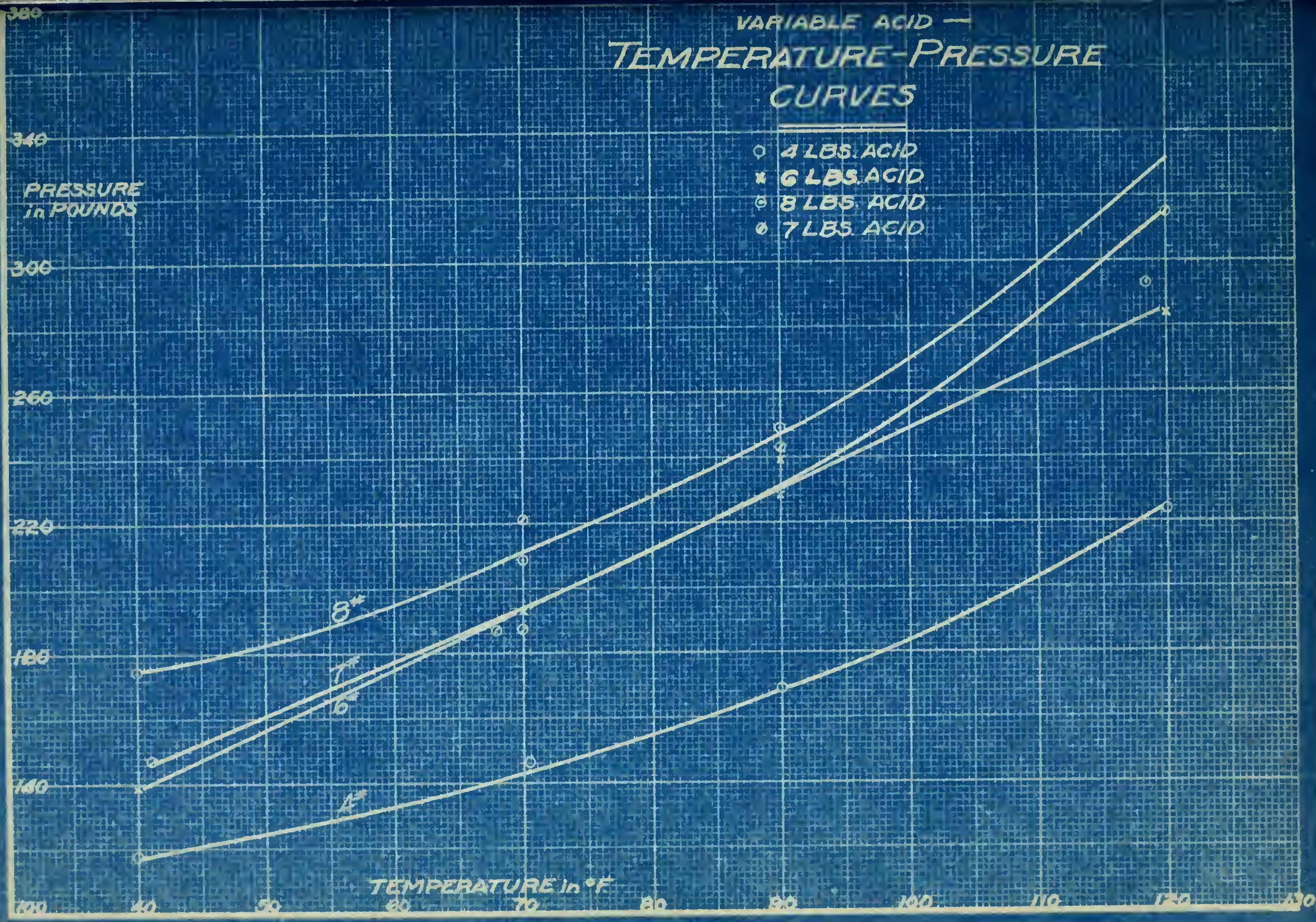
TEST DATA.

TEMPERATURE-PRESSURE DATA.

VARIABLE ACID

Water 33 gals.
Soda 20 lbs.

Run No.	Temp.	Max. Press.	Max. after Shaking
	°F.	#/□"	#/□"
ACID CHARGE--4 lbs.			
21	40	117.5	119.0
53	70.5	146.5	148.0
24	90	169.0	173.0
27	120	223.0	225.0
ACID CHARGE--6 lbs.			
25	40	138.8	143.0
29	70	193.0	196.0
26	90	240.0	245.0
32	90	228.0	260.0
33	120	284.0	294.0
ACID CHARGE--7 lbs.			
5	41	147.0	---
14	70	187.8	244.0
57	70	221.0	221.0
6	68	187.5	---
8	90	241.0	---
7	121	315.0	---
ACID CHARGE--8 lbs.			
28	40	174.5	198.0
30	70	208.5	280.0
31	90	249.0	303.0
36	118.5	292.5	396.0
59	120	387.0	393.0



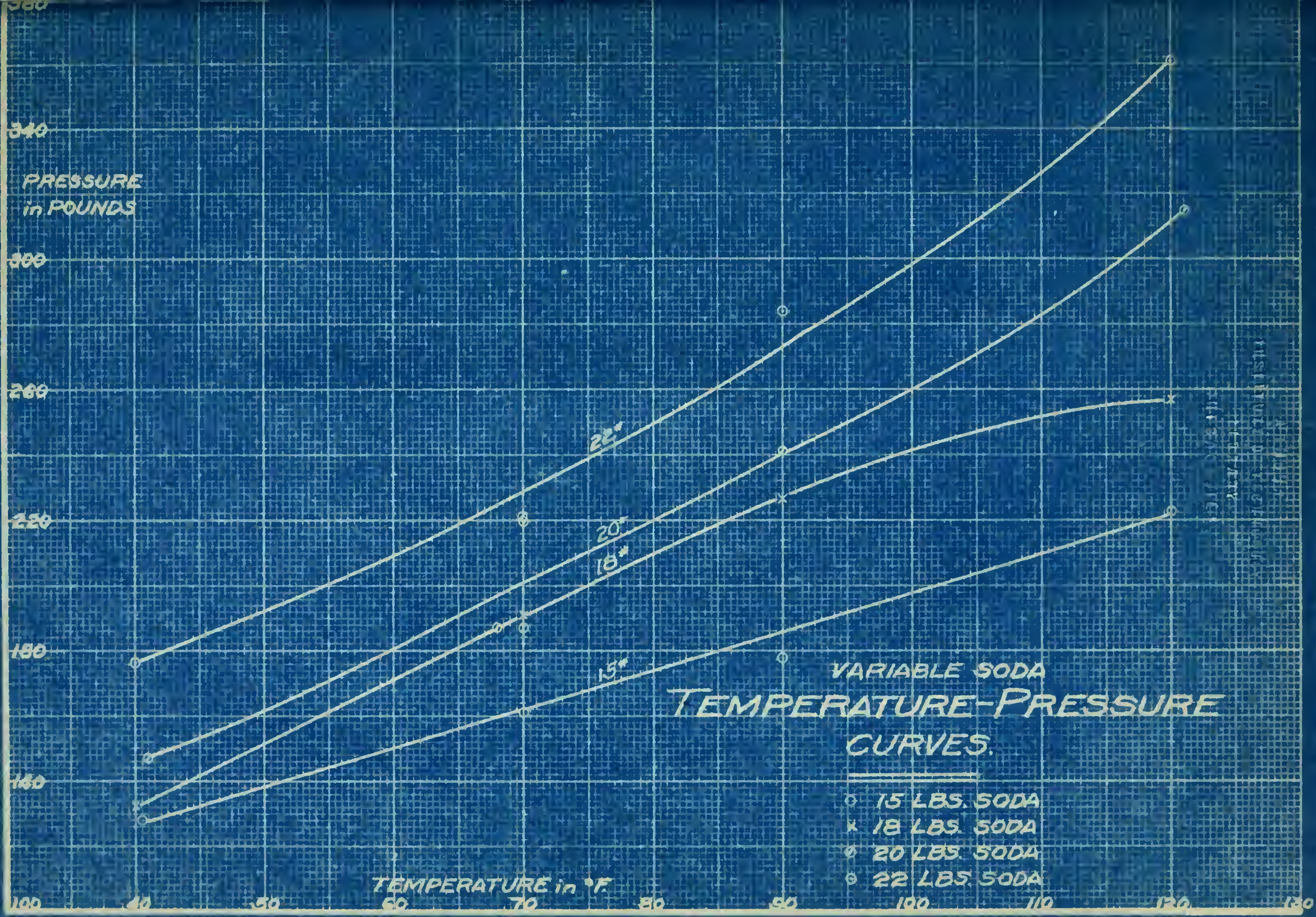
TEST DATA.

TEMPERATURE-PRESSURE DATA.

VARIABLE SODA CHARGE

Water 33 gals.
Acid 7 lbs.

Run No.	Temp.	Max. Press.	Max. after Shaking
	°F.	#/□"	#/□"
	SODA--CHARGE--15 lbs.		
34	40.5	120.8	142.0
38	70	161.0	227.0
41	90	178.0	269.0
42	120	222.5	328.0
	SODA CHARGE--18 lbs.		
35	40	132.5	139.0
39	70	191.0	212.0
43	90	226.3	277.0
44	120	257.0	342.0
	SODA CHARGE--20 lbs.		
5	41	147.0	---
57	70	221.0	221.0
14	70	187.8	244.0
6	68	187.5	---
8	90	241.0	---
7	121	315.0	---
	SODA CHARGE--22 lbs.		
37	40	176.5	177.0
40	70	220.0	247.0
45	90	284.0	285.0
46	120	361.0	361.0



VARIABLE SODA

TEMPERATURE-PRESSURE CURVES.

TEST DATA

Run # I.

Acid ---------- 7 lbs.

Soda ----------20 lbs.

Water -------- 20 gals.

Temperature -- 40° F.

Time Sec.	Pressure Obs.	 True
5	32.0	43.5
10	51.0	62.5
15	68.0	80.0
20	88.0	98.5
25	107.0	117.5
30	122.0	132.0
35	132.0	141.5
40	141.0	150.0
45	145.0	154.0
50	148.0	157.0
55	148.0	157.0
60	147.5	157.0
65	146.5	156.0

Run # 2.

Acid ---------- 7 lbs.

Soda --------- 20 lbs.

Water -------- 20 gals.

Temperature -- 71° F.

Time Sec.	Pressure Obs.	 True
10	37.0	62.0
20	68.0	99.0
30	110.0	131.5
40	151.0	157.5
50	169.0	174.0
60	177.0	183.5
65	178.0	185.0
70	179.5	186.5
75	179.8	187.5
80	179.8	187.5
85	179.8	187.5
90	179.5	187.3
95	179.0	187.0

Run # 3.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------20 gals.

Temperature-- 89° F.

Time	Pressure	
Sec.	Obs.	True
10	68.0	80.0
20	106.0	116.0
30	143.0	153.0
40	166.0	174.0
50	185.0	192.5
60	195.0	202.0
65	198.0	205.5
70	199.5	207.0
75	201.0	208.0
80	203.0	210.0
85	203.0	210.0
90	202.5	209.5
100	201.5	208.5

Run # 4.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------20 gals.

Temperature- 118° F.

Time	Pressure	
Sec.	Obs.	True
10	56.0	68.0
20	92.0	102.5
30	137.0	146.0
40	168.0	177.0
50	192.0	198.0
60	209.0	215.5
70	220.0	226.0
80	228.0	234.0
90	229.0	235.0
95	228.5	234.5
100	228.0	234.0
105	227.0	233.0

Run # 5.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---41° F.

Time Sec.	Pressure Obs.	True
10	61.0	45.0
20	98.0	83.0
30	127.0	103.0
40	145.0	133.0
50	155.0	143.0
60	158.0	146.0
70	159.0	147.0
80	159.0	147.0
90	159.0	147.0
100	158.5	146.5
110	158.5	146.5
120	158.3	146.3

Run # 6.

Acid----------- 7 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature----68° F.

Time Sec.	Pressure Obs.	True
5	49.0	32.0
10	78.0	63.0
15	105.0	90.0
20	131.0	118.0
30	165.0	153.0
40	185.0	175.0
50	192.0	182.0
55	196.0	186.0
60	197.0	187.0
70	197.3	187.3
75	197.3	187.3
110	197.3	187.3

TEST DATA

Run # 7.

Acid----------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature--121° F.

Time	Pressure	
Sec.	Obs.	True
10	110.0	95.0
20	178.0	167.0
30	229.0	221.0
40	265.0	258.0
50	288.0	281.0
55	300.0	295.0
60	305.0	300.0
65	310.0	305.0
70	315.0	310.0
75	320.0	320.0
80	320.0	320.0
90	320.0	315.0

Run # 8.

Acid----------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	101.0	86.0
20	151.0	139.0
30	184.0	174.0
40	205.0	195.0
50	222.0	212.0
60	229.0	220.0
70	236.0	228.0
80	241.0	233.0
100	244.0	236.0
130	246.0	238.0
170	248.0	240.0
200	248.0	240.0

Run # 9.

Acid---------- 7 lbs.
Soda----------20 lbs.
Water---------25 gals.
Temperature-- 41° F.

Time	Pressure	
Sec.	Obs.	True
5	30.0	13.0
10	50.0	33.0
15	71.0	54.5
20	90.0	75.0
30	126.0	112.0
46	148.0	137.0
50	155.0	143.5
60	157.5	145.5
70	156.5	144.7
80	155.5	143.6
90	154.5	143.0
100	153.5	142.3
110	153.0	142.0

Run # 10.

Acid---------- 7 lbs.
Soda----------20 lbs.
Water---------25 gals.
Temperature-- 90° F.

Time	Pressure	
Sec.	Obs.	True
10	70.0	54.0
20	108.0	93.0
30	145.0	132.5
40	170.0	158.5
50	186.0	175.0
60	200.0	190.0
70	211.0	202.0
80	218.0	208.0
90	221.0	212.0
120	224.5	215.0
140	225.0	216.0
170	223.5	214.0
200	222.5	213.0

Run # 11.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------25 gals.

Temperature--120° F.

Time Sec.	Pressure Obs.	 True
10	65.0	48.0
20	108.0	93.0
30	153.0	142.0
40	184.0	173.0
50	205.0	195.0
60	221.0	212.0
70	230.0	221.0
80	238.0	230.0
90	241.0	233.0
100	244.0	236.0
140	249.0	241.5
170	250.0	242.7
300	250.0	242.5

Run # 12.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------25 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True
10	66.0	50.0
20	110.0	95.0
30	142.0	129.0
40	164.0	153.0
50	179.0	168.0
60	187.0	176.0
70	192.0	181.0
80	194.5	184.5
90	195.5	185.0
100	197.0	187.0
110	197.0	187.0
120	196.5	186.0
130	196.0	186.0

Run #13.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------30 gals.

Temperature---70° F.

Time	Pressure	
Sec.	Obs.	True
10	75.0	60.0
20	123.0	110.0
30	153.0	142.0
40	177.0	165.8
50	194.0	183.0
60	202.0	193.0
70	205.0	195.0
80	206.5	196.5
90	207.2	197.0
100	207.2	197.0
120	207.2	197.0
140	207.2	197.0
180	207.0	197.0

Run # 14.

Acid----------- 7 lbs.

Soda-----------20 lbs.

Water----------35 gals.

Temperature----70° F.

Time	Pressure	
Sec.	Obs.	True
10	77.0	62.0
20	131.0	118.0
30	160.0	148.0
40	177.0	167.0
50	186.0	176.0
60	191.0	181.0
70	194.0	184.0
80	195.0	185.0
110	197.0	187.0
170	197.8	187.8
200	197.8	187.8
230	198.0	188.0
260	198.5	188.5

Run # 15.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------34 gals.

Temperature---70° F.

Time	Pressure	
Sec.	Obs.	True
10	91.0	84.0
20	154.0	143.0
30	182.0	169.0
40	198.0	185.0
50	206.0	192.0
60	210.0	196.0
70	211.0	197.0
80	211.0	197.0
95	211.0	197.0
105	210.7	196.3
120	210.0	196.0
130	209.5	195.5
140	209.3	195.3

Run # 16.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------30 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
10	62.0	57.0
20	96.0	89.0
30	125.0	116.0
40	141.0	131.0
50	152.0	141.0
60	155.0	144.0
70	157.0	146.0
80	157.6	146.6
110	157.6	146.6
120	157.2	146.2
130	157.0	146.0
140	157.0	146.0
150	156.8	145.8

TEST DATA

Run # 17.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------34 gals.

Temperature---41 ° F.

Time	Pressure	
Sec.	Obs.	True
5	52.0	47.0
15	110.0	107.0
20	132.0	122.0
25	144.0	134.0
30	155.0	144.0
35	162.0	151.0
40	168.0	157.0
45	172.0	160.0
50	174.0	162.0
55	174.3	162.3
60	174.0	162.0
70	172.5	160.5
80	171.8	159.8

Run # 18.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------30 gals.

Temperature--120 ° F.

Time	Pressure	
Sec.	Obs.	True
5	64.0	59.0
10	102.0	95.0
15	135.0	125.0
20	168.0	157.0
25	195.0	182.0
30	215.0	200.0
40	246.0	230.0
50	273.0	257.0
60	289.0	271.0
70	301.0	282.0
80	307.0	288.0
90	308.0	289.0
105	309.0	290.0

Run # 19.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------30 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	85.0	82.5
20	131.0	122.0
30	165.0	151.0
50	205.0	185.0
70	224.0	202.0
90	234.5	210.0
120	240.0	215.0
150	242.5	217.5
180.	244.0	219.0
210	245.0	220.0
240	245.4	220.4
270	246.0	221.0
300	246.0	221.0

Run # 20.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------34 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	80.0	79.0
20	150.0	145.0
30	205.0	195.0
40	228.0	216.0
50	240.0	227.0
60	246.0	232.0
70	248.0	233.0
80	250.0	235.0
90	250.0	235.0
100	250.0	235.0
110	250.0	235.0
120	250.0	235.0
140	249.0	234.0

Run # 21.

Acid---------- 4 lbs.

Water---------33 gals.

Soda----------20 lbs.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
5	38.0	42.5
10	59.0	60.0
15	83.0	80.0
20	103.0	98.0
25	114.0	107.0
30	124.0	116.0
35	126.0	117.5
40	126.0	117.5
45	125.5	117.0
50	125.0	116.5
55	124.5	116.3
60	124.0	116.0
65	123.5	115.5

Run # 22.

Acid---------- 4 lbs.

Water---------33 gals.

Soda----------20 lbs.

Temperature---70° F.

Time	Pressure	
Sec.	Obs.	True
5	46.0	48.0
10	74.0	73.0
15	99.0	95.0
20	121.0	112.5
30	149.0	137.5
40	158.0	145.5
50	160.5	147.5
60	161.0	148.0
70	161.3	148.3
80	161.3	148.3
90	161.3	148.3
110	161.3	148.3
120	161.0	148.0

Run # 23.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------34 gals.

Temperature--120° F.

Time	Pressure	
Sec.	Obs.	True
10	125.0	122.0
20	190.0	180.0
30	132.0	116.0
40	286.0	271.0
50	312.0	296.0
60	325.0	308.0
70	330.0	313.0
80	335.0	318.0
90	335.0	318.0
100	335.0	318.0
120	335.0	318.0
140	335.0	318.0
160	334.0	317.0

Run # 24.

Acid----------- 4 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature----90° F.

Time	Pressure	
Sec.	Obs.	True
10	84.0	70.0
20	134.0	122.0
30	167.0	151.0
40	180.0	164.0
50	184.0	167.0
60	186.0	169.0
70	186.0	169.0
80	186.0	169.0
90	186.0	169.0
100	185.5	168.5
110	185.5	168.5
120	185.0	168.0
130	184.5	167.5

Run # 25.

Acid---------- 6 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---40° F.

Time Sec.	Pressure Obs.	 True
10	67.0	54.0
20	102.0	88.0
30	132.0	116.0
40	143.0	127.0
50	150.0	134.0
60	153.0	137.0
70	154.5	138.0
80	155.0	138.5
95	155.0	138.5
105	155.0	138.5
115	155.2	138.6
125	155.2	138.6
135	155.2	138.6

Run # 26.

Acid---------- 6 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---90° F.

Time Sec.	Pressure Obs.	 True
10	86.0	72.0
20	143.0	126.0
30	177.0	161.0
40	201.0	185.0
50	219.0	201.0
60	231.0	212.0
70	240.0	221.0
80	244.0	224.0
100	250.5	230.0
130	256.0	236.0
160	258.0	238.0
190	259.0	239.0
240	260.0	240.0

Run # 27.

Acid---------- 4 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature--120° F.

Time Sec.	Pressure Obs.	Pressure True
10	95.0	92.5
20	165.0	157.0
30	195.0	184.0
40	215.0	202.0
50	225.0	213.0
60	231.0	219.0
70	231.0	219.0
80	233.0	221.0
90	235.0	223.0
100	235.0	223.0
120	235.0	223.0
130	234.0	222.0
140	234.0	222.0

Run # 28.

Acid----------- 8 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature----40° F.

Time Sec.	Pressure Obs.	Pressure True
5	58.0	45.0
10	89.0	75.0
15	112.0	97.0
20	134.0	118.0
25	149.0	133.0
30	164.0	148.0
35	170.0	154.0
40	181.0	164.0
50	189.0	172.0
60	191.5	174.5
80	190.2	173.2
90	190.0	173.0
100	189.0	172.0

Run # 29.

Acid---------- 6 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True
10	88.0	74.0
20	150.0	134.0
30	179.0	163.0
40	196.0	179.0
50	206.0	189.0
60	209.0	192.0
70	210.0	193.0
80	210.0	193.0
90	209.5	192.5
100	209.2	192.5
110	209.0	192.3
120	208.5	191.8
130	208.0	192.3

Run # 30.

Acid---------- 8 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True.
10	110.0	96.5
20	153.0	139.0
30	182.0	165.0
40	202.0	185.0
50	213.0	196.0
70.	221.0	203.0
90	223.0	204.5
120	223.4	204.9
175	224.2	205.3
235	225.2	206.7
295	226.0	207.5
355	227.0	208.5
385	227.0	208.5

Run # 31.

Acid---------- 8 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
5	40.0	46.0
10	50.0	57.0
15	105.0	102.0
20	145.0	140.0
25	165.0	158.0
40	210.0	198.0
45	240.0	227.0
50	250.0	238.0
55	255.0	240.0
60	260.0	245.0
70	263.0	248.0
80	263.0	248.0
90	267.0	249.0
130	267.0	249.0

Run # 32.

Acid---------- 6 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	101.0	84.8
20	164.0	144.0
30	201.0	179.0
40	226.0	204.0
50	243.0	219.0
60	248.0	224.0
70	252.0	227.0
80	253.0	228.0
90	253.2	228.2
100	253.2	228.2
110	253.2	228.2
120	253.2	228.2
140	253.2	228.2
160	253.2	228.2

Run # 33.

Acid---------- 6 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature--120° F.

Time	Pressure	
Sec.	Obs.	True
10	105.0	100.0
20	180.0	170.0
30	224.0	211.0
40	255.0	240.0
50	275.0	260.0
60	285.0	269.0
70	296.0	281.0
80	296.0	281.0
90	297.0	281.0
100	300.0	284.0
110	300.0	284.0
120	300.0	284.0
140	300.0	284.0

Run # 34.

Acid---------- 7 lbs.

Soda----------15 lbs.

Water---------33 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
10	42.0	44.0
20	74.0	74.0
30	96.0	96.0
40	111.0	110.0
50	117.0	116.0
60	119.5	118.0
70	120.5	119.0
80	120.5	119.0
90	120.5	119.0
120	121.5	120.0
150	121.8	120.3
180	121.8	120.3
210.	122.3	120.8

Run # 35.

Acid---------- 7 lbs.

Soda----------18 lbs.

Water---------33 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
5	34.0	36.0
10	57.0	59.0
15	79.0	79.0
20	97.0	97.0
25	112.0	111.0
30	124.0	123.0
35	130.0	128.0
40	132.0	129.5
50	134.5	131.5
60	134.5	131.5
70	135.0	132.5
80	134.8	132.3
100	134.2	131.7
110	134.0	131.5

Run # 36.

Acid---------- 8 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature--118.5°F.

Time	Pressure	
Sec.	Obs.	True
10	95.0	105.0
20	160.0	165.0
30	205.0	204.0
40	240.0	235.5
50	265.0	263.0
60	280.0	275.0
70	290.0	283.0
80	294.0	287.0
90	295.0	288.0
120	295.0	288.0
140	295.0	288.0
160	295.0	288.0
210	295.0	288.0
300	298.0	291.0

Run # 37.

Acid---------- 7 lbs.

Soda----------22 lbs.

Water---------33 gals.

Temperature---40° F.

Time Sec.	Pressure Obs.	 True
5	41.0	43.0
10	70.0	69.0
15	96.0	96.0
20	119.0	118.0
25	134.0	132.0
30	149.0	146.5
35	161.0	159.0
40	171.0	168.5
50	178.0	175.5
60	179.0	176.5
70	179.5	176.5
80	178.5	170.0
90	176.5	174.0

Run # 38.

Acid---------- 7 lbs.

Soda----------15 lbs.

Water---------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True
5	34.0	36.0
10	62.0	63.0
15	85.0	85.0
20	111.0	110.0
25	130.0	129.0
30	141.0	139.0
35	146.0	143.0
40	152.0	150.0
45	157.0	155.0
50	159.0	157.0
55	161.0	158.0
65	162.0	161.0
115	162.0	161.0

Run # 39.

Acid---------- 7 lbs.

Soda----------18 lbs.

Water---------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	Pressure True
10	80.0	80.0
20	120.0	118.5
40	165.0	163.0
60	182.0	179.0
70	184.0	181.0
80	187.0	184.0
90	180.0	186.0
100	190.0	186.5
110	191.0	188.0
120	191.0	188.0
160	193.0	189.5
170	193.5	190.0
200	194.0	191.0

Run # 40.

Acid---------- 7 lbs.

Soda----------22 lbs.

Water---------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	Pressure True
10	82.0	82.0
20	135.0	133.0
35	169.0	167.0
40	192.0	189.0
50	205.0	201.0
60	213.0	209.0
70	219.0	215.0
80	220.0	215.0
100	223.0	218.0
120	224.5	219.0
155	224.5	219.0
165.0	225.0	220.0
195	225.5	220.

Run # 41.

Acid---------- 7 lbs.

Soda-----------15 lbs.

Water----------33 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	84.0	81.0
20	139.0	132.0
30	162.0	155.0
40	174.0	166.0
50	181.5	173.0
60	186.0	176.0
70	186.5	177.5
80	187.0	178.0
110	187.0	178.0
120	187.0	178.0
130	186.8	177.8
140	186.5	177.5
150	186.5	177.5

Run # 42.

Acid---------- 7 lbs.

Soda-----------15 lbs.

Water----------33 gals.

Temperature--120° F.

Time	Pressure	
Sec.	Obs.	True
10	75.0	85.0
20	135.0	140.0
30	173.0	172.0
40	195.0	195.0
50	200.0	209.5
60	221.0	218.0
70	221.0	218.0
80	221.0	218.0
90	225.0	222.0
100	225.5	222.5
120	225.5	222.5
140	225.5	222.5
150	225.5	222.5

Run # 43.

Acid---------- 7 lbs.

Soda-----------18 lbs.

Water----------33 gals.

Temperature---90° F.

Time Sec.	Pressure Obs.	 True
10	99.0	95.0
20	155.0	148.0
30	197.0	192.0
40	220.0	209.0
50	232.0	220.0
60	237.0	224.5
65	237.0	224.5
70	239.0	225.0
75	239.2	225.2
80	238.8	226.3
85	238.5	226.0
90	238.5	226.0
105	237.7	225.2

Run # 44.

Acid---------- 7 lbs.

Soda-----------18 lbs.

Water----------33 gals.

Temperature--120° F.

Time Sec.	Pressure Obs.	 True
5	52.0	65.0
10	90.0	98.0
20	154.0	157.0
25	180.0	180.0
30	200.0	200.0
40	230.0	226.0
45	235.0	231.0
50	240.0	235.5
55	250.0	245.0
65	256.0	251.0
70	257.0	252.0
75	261.0	257.0
95	261.0	257.0

Run # 45.

Acid---------- 7 lbs.

Soda----------22 lbs.

Water---------33 gals.

Temperature---90° F.

Time	Pressure	
Sec.	Obs.	True
10	100.0	108.0
20	165.0	168.0
30	205.0	205.0
40	231.0	228.0
50	255.0	250.0
60	265.0	260.0
70	270.0	265.0
80	276.0	271.0
90	285.0	279.0
120	284.0	278.0
140	287.0	281.0
150	290.0	284.5
180	287.0	281.0

Run # 46.

Acid---------- 7 lbs.

Soda----------22 lbs.

Water---------33 gals.

Temperature--120° F.

Time	Pressure	
Sec.	Obs.	True
10	115.0	120.0
20	180.0	180.0
30	245.0	240.0
40	285.0	279.0
50	315.0	305.0
60	335.0	325.0
70	345.0	334.0
80	352.0	345.0
110	375.0	360.0
120	375.0	360.0
130	376.0	361.0
180	376.0	361.0
200	374.0	359.0

Run # 47.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---54.5° F.

Time Sec.	Pressure Obs.	 True
10	69.0	68.0
20	112.0	108.0
30	147.0	141.0
40	164.0	157.0
45	169.0	162.0
50	172.0	165.0
55	175.0	168.0
60	176.5	169.5
65	176.5	169.5
70	176.5	169.5
80	177.0	170.0
130	177.0	170.0
140	176.5	169.5

Run # 48.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature---98° F.

Time Sec.	Pressure Obs.	 True
10	75.0	85.0
20	145.0	150.0
30	193.0	193.0
40	220.0	218.0
50	243.0	236.0
60	256.0	249.0
70	261.0	254.0
80	264.0	258.0
85	264.0	258.0
90	264.0	258.0
100	267.0	261.0
110	270.0	264.0
180	270.0	264.0

Run # 50.

Acid---------- 7 lbs.

Soda-----------20 lbs.

Water----------20 gals.

Temperature-- 71° F.

Time	Pressure	
Sec.	Obs.	True
10	64.0	62.0
20	104.0	99.0
30	139.0	132.0
40	165.0	157.0
50	183.0	174.0
60	193.0	184.0
70	196.0	187.0
80	198.0	188.0
85	197.0	187.5
95	196.5	187.5
105	195.5	186.5
115	195.0	186.0
160	192.5	183.5

Run # 51.

Acid---------- 7 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature--- 68° F.

Time	Pressure	
Sec.	Obs.	True
10	76.0	73.0
15	102.0	97.0
20	124.0	117.0
30	160.0	152.0
35	170.0	163.0
40	178.0	170.0
50	191.0	183.0
55	194.0	185.0
60	197.0	188.0
65	199.0	189.5
70	200.0	198.5
75	200.5	191.0
150	200.5	191.0

Run # 52.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water-------- 20 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
5	40.0	38.0
10	68.0	65.0
15	90.0	86.0
20	109.0	103.5
25	124.0	117.0
35	149.0	141.5
45	161.0	163.0
50	162.0	154.0
55	162.5	154.5
60	162.0	154.0
70	160.5	152.5
85	159.5	151.5
100	158.5	150.5

Run # 53.

Acid---------- 4 lbs.

Soda----------20 lbs.

Water---------30 gals.

Temperature-- 71.5° F.

Time	Pressure	
Sec.	Obs.	True
5	38.0	36.0
10	61.0	59.0
15	90.0	86.0
20	116.0	110.0
25	136.0	128.5
30	148.0	140.5
40	153.0	145.0
45	154.0	146.0
50	154.5	146.5
60	154.5	146.5
70	154.0	146.0
90	153.0	145.0
120	151.5	143.5

Run # 55.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------34 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	Pressure True
10	103.0	81.5
20	155.0	139.5
30	187.0	168.5
40	205.0	185.5
50	212.0	192.0
55	215.0	194.5
60	215.5	196.0
65	216.5	196.0
70	217.0	196.5
90	217.0	196.5
110	217.5	197.0
140	217.5	197.0
150	217.0	196.5

Run # 56.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------33 gals.

Temperature--110° F.

Time Sec.	Pressure Obs.	Pressure True
10	98.0	104.0
20	170.0	170.0
25	194.0	194.0
30	216.0	214.0
35	240.0	233.0
40	254.0	246.0
45	265.0	253.0
50	267.0	255.0
55	271.0	263.0
60	274.0	266.0
65	275.0	267.0
70	276.0	268.0
145	276.0	268.0

Run # 57.

Acid---------- 7 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True
10	85.0	92.0
20	143.0	145.0
30	178.0	176.0
40	201.0	198.0
50	214.0	210.0
60	219.0	215.0
70	221.0	217.0
90	224.0	219.0
100	225.0	220.0
110	226.0	221.0
120	226.0	221.0
130	225.0	220.0
180	225.0	220.0

Run # 58.

Acid---------- 7 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature---70° F.

Time Sec.	Pressure Obs.	 True
10	125.0	130.0
20	190.0	188.0
30	230.0	224.0
40	270.0	260.0
50	285.0	274.0
60	298.0	287.0
70	305.0	294.0
80	308.0	297.0
85	311.0	300.0
90	311.0	300.0
100	311.0	300.0
120	311.0	300.0
180	311.0	300.0

Run # 59.

Acid----------- 8 lbs.

Soda-----------20 lbs.

Water----------33 gals.

Temperature---120° F.

Time Sec.	Pressure Obs.	Pressure True
10	105.0	110.0
20	185.0	183.0
30	235.0	228.0
40	279.0	269.0
50	310.0	299.0
60	335.0	323.0
70	360.0	346.0
90	384.0	367.0
110	396.0	377.0
130	402.0	382.0
150	405.0	285.0
170	407.0	387.0
210	407.0	387.0

Run # 60.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------36 gals.

Temperature---90° F.

Time Sec.	Pressure Obs.	Pressure True
10	110.0	115.0
20	190.0	188.0
30	240.0	233.0
40	270.0	260.0
50	285.0	274.0
60	286.0	275.0
65	287.0	276.0
70.	287.0	276.0
80	287.0	276.0
90	287.0	276.0
100	287.0	276.0
110	287.0	276.0
120	287.0	276.0

Run # 61.

Acid----------7 lbs.

Soda----------20 lbs.

Water---------20 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
15	65.0	75.0
20	80.0	88.0
25	95.0	101.0
30	120.0	125.0
35	135.0	140.0
40	142.0	147.0
45	149.0	152.0
50	150.0	153.0
55	152.0	156.0
60	152.0	156.0
80	148.0	151.0
100	147.0	150.0
120	146.0	148.0

Run # 62.

Acid---------- 7 lbs.

Soda----------20 lbs.

Water---------38 gals.

Temperature---40° F.

Time	Pressure	
Sec.	Obs.	True
5	50.0	61.0
10	135.0	140.0
15	170.0	181.0
20	205.0	202.0
25	235.0	229.0
30	255.0	246.0
35	275.0	265.0
40	285.0	274.0
45	286.0	275.0
50	287.0	276.0
55	287.0	276.0
60	287.0	276.0
90	287.0	276.0

CHAPTER 4.

SAMPLE CALCULATIONS.

Calculation of air space. The volume of air space in any given run is the net volume of the tank minus the volume of solution. The net volume of the tank was the gross volume minus the combined volume of guard, acid bottle and acid and was calculated as follows:

Gross volume of tank (from capacity test) ----------------------------40.13 gals.

Volume of guard (estimated) 10 cu. in.

Volume of acid bottle (estimated) 25 cu. in.

Volume of acid (calculated) 105 cu. in.

Total ------------ 140 cu. in. =.60 gal.

Net volume of tank -----------39.53 gal.

The volume of acid was calculated from the expression:

$$V = \frac{W \times 1728}{P \times 62.4}$$

Where W is weight of acid (7 #) and P is

specific gravity of acid (1.84).

The volume of solution was abtained by interpolating in the data from the capacity test. For instance, referring to Run # 1:-

Height of solution = 24 5/16" = 24.31"

Interpolating between 21 and 22 gallons, the volume of solution is found to be 21.06 gals. The volume of air space was then 39.53-21.06, or 18.47 gals., and the ratio of air space to solution was 18.47 to 21.06 or 85.50 %.

PART IV.

CONCLUSIONS

There was practically no room for error in conducting the capacity test and the three sets of observations checked very closely, so that the average values are about as accurate as they could be made.

The results obtained in the closed nozzle test, taking up the groups as given in the introduction, were as follows:-

1. Air-space pressure relation.-- The curves plotted from this test data follow very closely the theoretical curves indicated in the introduction and prove that as the air space approaches zero, the pressures approach infinity. The solubility of the CO_2 gas at the greater pressure modifies the actual curves obtained. These curves clear up the points which were raised in the previous investigation of 1908, mentioned in the introduction.

2. Temperature-pressure relation.-- The theoretical temperature curves should be

practically straight lines. The actual curves obtained are nearly straight lines. The normal temperature-pressure curve, in which the greatest number of points were obtained, is a straight line the slope of which is far greater than Charles' law alone would show, which bears out the fact mentioned in the object and introduction, that the increase in pressure with temperature in due principally to the greater solubility of CO_2 gas at the lower temperatures. The actual amount of CO_2 dissolved was found to be 14% of the total gas generated at 40° F. and only 3% of the total amount of gas at 120° F.; hence there will be a considerably greater proportion of the gas available for generating pressure at the higher temperatures. Still another factor tending to increase the pressures at higher temperatures in the fact that at those higher temperatures the chemical reaction is more rapid, resulting in a

violent ebullition which in turn results in a more complete reaction between acid and soda.

3. Acid-pressure relation.-- The theoretical amount of acid necessary to act completely with 20 pounds of soda (assumed 100% C. P.) would be about 12 pounds (assuming acid 94% C. P.) Hence there is an excess of soda, and the curves should have the form indicated below the point "a" in figure "C" of the introduction. The curves actually obtained have this general form. The actual maximum pressure curves are straight lines, while the "maximum after shaking" curves approach the theoretical curves more closely.

4. Soda-pressure relation.-- It was shown in the above paragraph that only 12 pounds of soda are required to react completely with the given amount of acid. Hence, since 15 pounds was the minimum weight of soda used, the curves should have the slope

indicated beyond point "a" in figure "C" of the introduction, or should be horizontal lines. The actual curves obtained do not follow this form due to the increased amount of excess soda at the higher charges, and consequent increase in initial maximum pressures before shaking. After shaking, however, all the soda and acid react giving results which check more closely with the theory as shown by the approximately horizontal "maximum after shaking" curves.

There seemed to be a great many factors which affected the results, and part of these conditions are at least indefinite. After careful consideration of the results, it is our opinion that the most important factor is the amount of undissolved soda, depending on the amount of stirring and the charges: the greater the amount of undissolved soda, the higher the maximum pressure attained.

The reason for this, we believe, is as follows: If we had a solution in which all the soda was perfectly dissolved, only a certain portion of the acid would come in contact and react with part of the solution, and the maximum pressures developed would depend upon the proportions which reacted. Now if there be a considerable amount of undissolved soda, it will drop to the bottom of the tank and react with the acid and the maximum pressure attained will be greater than before. On the other hand, if the tank be shaken, the acid will be brought into contact with all parts of the solution, and the maximum possible pressure will be reached regardless of the amount of undissolved soda.

Another important factor, especially in the temperature-pressure relation, is the solubility of CO_2 gas at various temperatures and pressures.

CONCLUSIONS.

The results obtained from this investigation were very satisfactory. The effect of variations in the four factors, i. e., air or gas space, temperature, acid, and soda, upon the maximum pressures developed in an acid-soda extinguisher with closed nozzle, was determined thus fulfilling our object. Further tests are desirable to show the relation between these closed nozzle tests and the open nozzle tests under the same conditions.

APPENDIX

In the course of the tests a number of minor difficulties were encountered. The first of these was the fact that there were a number of pin-holes thru the solder at the neck of the tank, and some pressure was lost due to these small leaks. It was found, however, that the most serious leaks developed probably did not lower the maximum pressure attained by more than two or three pounds, and they were accordingly neglected.

Probably the most serious difficulty was due to the inaccuracy of the gauges, especially the 300# gauge. The latter was calibrated at the beginning of the tests, and was not calibrated again for several days, when its readings were found to be widely different, and thereafter was necessary to calibrate gauges at least once, and often two or three times a day. But there was no accurate calibration

which could be used for the first few days' runs, and these calibrations were estimated as follows: One run, out of each days group of runs was repeated, and the corrected pressure readings tabulated. It was then assumed that the rise in pressure was uniform and identical in both the original and check tests, and so the corrected pressures were set down opposite the gauge readings corresponding to their respective time intervals. This gave a series of gauge and true readings; in other words, calibration data, and a calibration curve was accordingly plotted, drawing in a straight line curve between the average points. This curve was then used as a calibration for that particular day's runs. This method was found to give fairly satisfactory results, and the best to be expected under the circumstances.

The gauge calibrations are given on the following sheets.

CALIBRATION OF 300 # GAUGE.

True.	1/15/17	2/19/17	2/20/17	2/26/17	3/5/17
0	7.5	14			
10	16.5	23.2	26	9.5	12
20	25.5	33	36	19	21.5
30	35	43	45.8	28	30.5
40	44	53	56	38	40.5
50	54	63	66.6	48.5	51.5
60	63.5	73.5	77.1	58.5	62
70	73.5	84	87	69	72.5
80	83	94	97.3	80	83
90	92.2	104	107.2	90	94
100	101.5	115	119.1	100.5	104.5
110	111.5	126	129.9	111	115
120	122	136	140	121.5	126
130	132	146.5	150	132.5	137
140	141	156.6	160.2	142.5	147
150	150.5	166	170.2	152.5	157.5
160	160	176.5	181.4	162.5	167.5
170	169	187	191.7	172.5	178.5
180	179	197	201.7	183	189
190	188.5	207	212	193.5	195.5
200	198	218	222	204	210
210	207	228.5	233.6	215.5	221
220	217	239	244	225	232.5
230	226	250	255	236	244
240	236	260	265	247	254
250	246	270	276	259	265
260	256	281	286	269.5	278
270	265.5	293	297.5	281.5	289
280	275			292	300

APPENDIX.

CALIBRATION OF 300# GAUGE.

True.	3/12/17	3/26/17(AM)	3/26/17(PM)
10	10	13	16.5
20	20	22	26
30	29	32	36.5
40	39.5	42	47
50	50	53	58
60	60.5	63	69
70	71.5	74.5	80
80	81.5	85.5	91.
90	92.5	96.5	101.5
100	103.2	106.5	112
110	113.5	118	124
120	124.5	129.5	135.5
130	135.5	140	146
140	145.5	150.5	156.5
150	156.5	161.5	167
160	166.5	172	177.5
170	176.5	183.5	188.5
180	187.5	193.5	199
190	198	205.5	210
200	208.5	216	221
210	219.5	227.5	233.5
220	231.5	238.5	244.2
230	243	250	256
240	254	261.5	267.5
250	264.5	274.5	280
260	276	---	291

APPENDIX.

CALIBRATION OF 500# GAUGE.

True.	3/12/17	3/26/17	4/5/17
36	15	15	15
40	25	29	25
60	45	50	49
80	70	70	71
100	92	89	94
120	110	115	115
140	135	135	135
160	155	159	160
180	180	180	182
200	202	201	203
220	222	222	225
240	247	248	248
260	267	268	270
280	286	288	291
300	306	312	211
320	327	330	332
340	347	355	354
360	370	375	376
380	395	398	400
400	417	420	421
420	435		442

CALIBRATION OF 500 # GAUGE.

True.	2/19/17	2/20/17	2/26/17	3/5/17
20	13	13		
40	35	38	20	25
60	57.5	60	45	45
80	82	83	70	70
100	103	105	90	92
120	123	125	113	115
140	145	145	133	135
160	169	170	155	157
180	190	190	176	180
200	213	213	201	200
220	232	233	223	223
240	255	255	245	245
260	275	275	262	264
280	295	295	287	286
300	317	320	308	309
320	337	337	327	330
340	358	359	348	353
360	382	381	372	375
380	405	405	395	398
400	425	424	418	418
420	448	---	435	439
440	469	---	455	460
460	495	---	482	481